The thermal evolution of Jupiter-like exoplanets

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1. Context

The detection and characterisation of exoplanets is an important goal in astrophysics for the coming years. With the help of ground-based telescopes such as, the VLT and space telescopes such as the recently launched James Webb Space Telescope or the future Ariel space telescope, we have access to an ever larger database of exoplanets. Theoretical models to understand the populations of planets observed need to be continuously improved and adapted to the observations.

2. Methods

- In order to model the structure of an exoplanet we propose to separate a given planet into two sections, the first comprising the core and the interior (interior model) and the second the atmosphere (atmosphere model), as shown in figure 1.
- We use the 1d radiative-convective model Exo-REM to model the atmosphere. Exo-REM solves self-consistently exoplanetary atmospheres at radiative-equilibrium taking into account the chemistry in and out of equilibrium. Hence providing an advanced precise model of atmospheres.
- The interior model used is Exoris which comprises of a set of equations of state, radial shells are adjusted to match inputted parameters. The equations of state a modifiable and inter-compatible which paves the way for an exploration of various internal structures.
- The models provide pressure-temperature profiles for a given set of parameters. We can link these profiles between models to generate a complete planetary profile, as shown in figure 2.

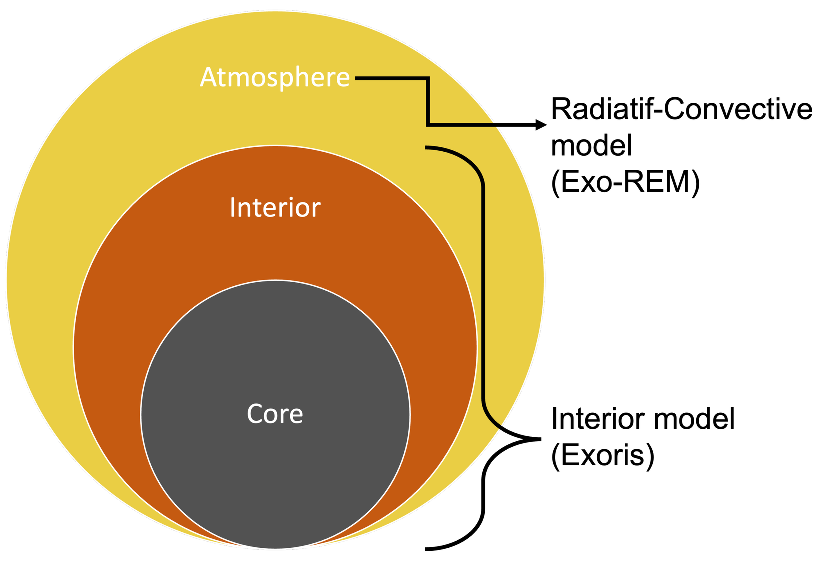

Figure 1: Proposed simple model of exoplanet structure using two sub-models

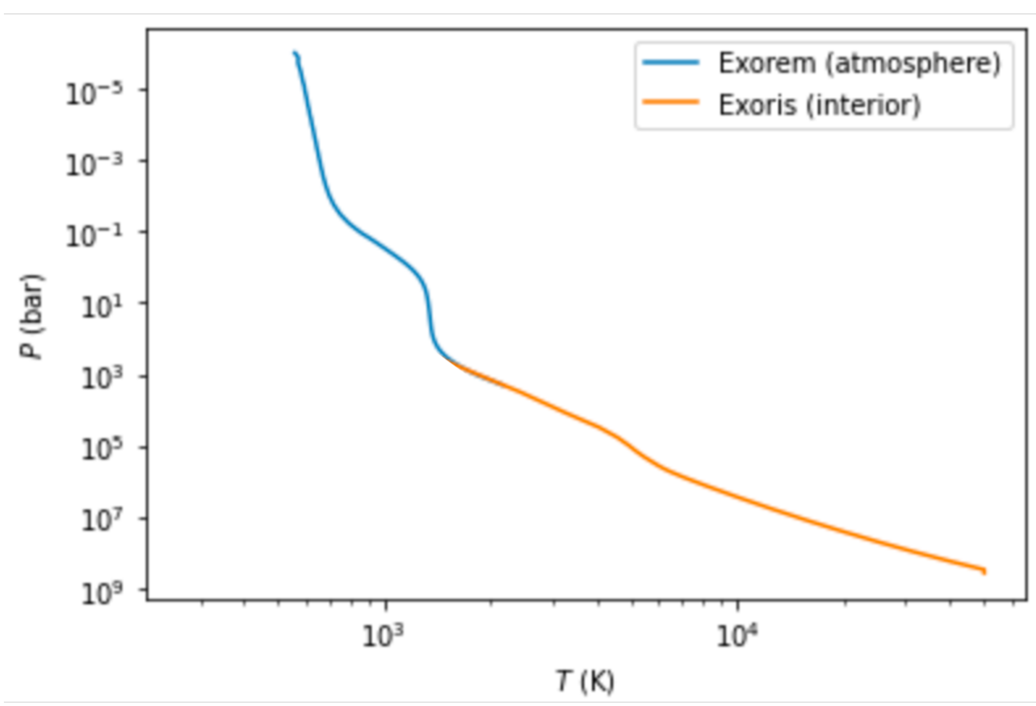

Figure 2: Example of thermal structure of an irradiated exoplanet $T_{irr} = 1200K$

3. Preliminary results

- We chose here to link a grid of models for varying irradiation temperatures, as shown in figure 3.
- The evolution curve of the case example of the inflated radius gas giant HD209458b can hence be plotted and its current internal temperature determined, as shown in figure 4. This subsequent result paves the way for the exploration of evolutionary tracks of inflated Jupiter-like planets.

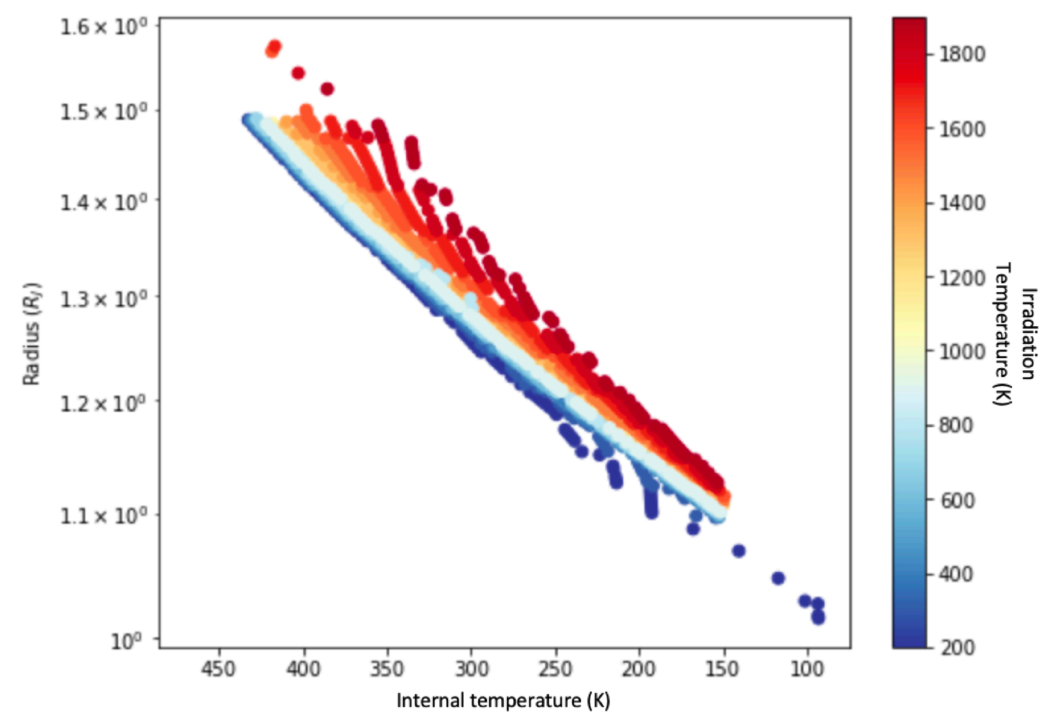

Figure 3: Simulated radius evolution of planets at various irradiation temperatures

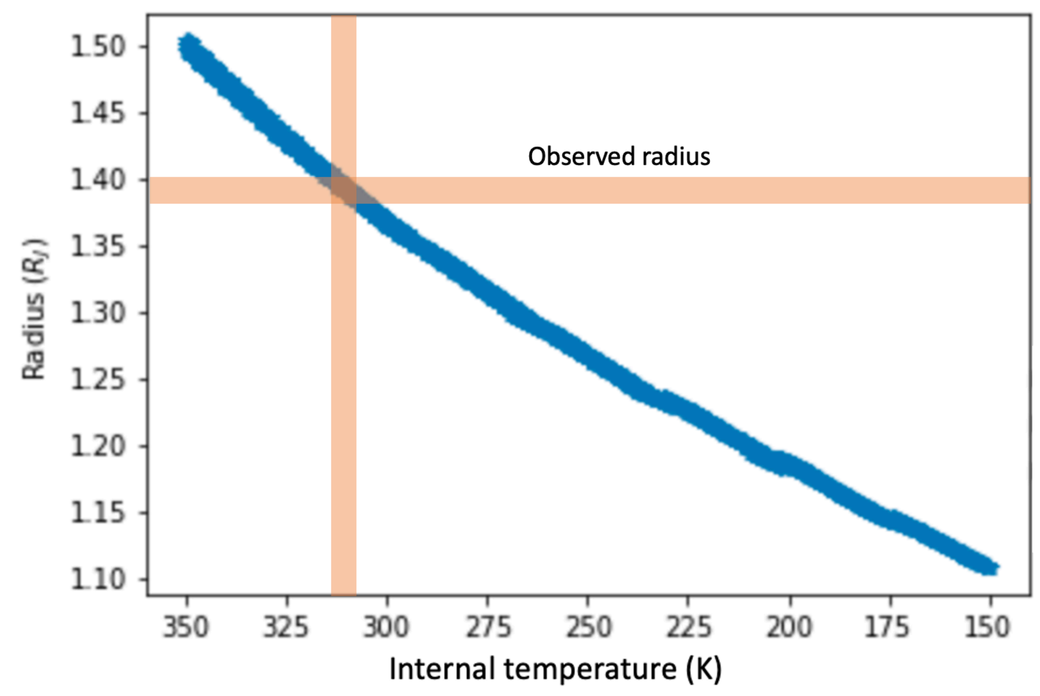

Figure 4: Simulated radius evolution of HD209458b $T_{irr} = 1400K, M = 0.69J$

4. Future Work

- Further work is required to improve the quality of the grids and improve linkage between the two models.
- We wish to explore further physical parameters such as the impact of clouds on evolution tracks and the difference we might find with highly debated fingering convection dynamics in the atmosphere.
- We wish to explore the impact that planetary cores might have on evolution tracks and potentially explore the impact of diffused cores.
- Exorem produces transit and emission spectrum's for a given atmosphere. Hence we hope to explore the spectral evolution of a given exoplanet. Developing and interface with observed spectrum's will help determine age and structure of exoplanets taking into account the complex atmospheric chemistry and internal structure.

References

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